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ABSTRACT

Focusing on teaching situations with varying degrees of teacher knowledge, an interpretive study examined the effects of science teacher subject-matter knowledge on classroom questioning and other forms of discourse. Four biology and life science teachers participated in the first year of two year-long studies (the second is in progress). All of the teachers were interns or student teachers in a fifth-year teacher education program, and taught at the 9-12 grade level in San Francisco Bay area public high schools. The relative subject-matter knowledge of the teachers on 15 biological topics was determined using quantitative and qualitative discourse analysis. Results revealed that when teachers did not have a strong understanding of the topic they were teaching, they were likely to use frequent low cognitive-level questions to control classroom conversation, and student participation was minimal. In high teacher-knowledge classes, teachers asked fewer questions and student participation and questioning was high. (Figures of the study's conceptual framework, the middle strand of the conceptual framework (speech activities level), the rate of low cognitive-level teacher questioning, the frequency of student speech acts, student questioning rate, ratio of teacher to student questions, and class time spent on other activities before class discussion are included, and 19 references are appended.) (MM)

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Why Do You Ask?

The Effects of Science Teacher Subject-Matter Knowledge on Teacher Questioning and Classroom Discourse

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Abstract

Research was done on the relationship between the subject-matter knowledge of new biology teachers and discourse in their classrooms. During two year-long studies, card sorts and other methods were used to identify high and low teacher-knowledge topics for a total of eight teachers. This paper focuses on the first year of the study, which compared discourse in pairs of high and low-knowledge classes for each of four teachers. When teachers led discussions on topics for which they had weak subject-matter knowledge, they asked numerous questions, especially low cognitive-level questions. Student talk tended to consist of brief responses to teacher questions. In high teacher-knowledge classes, teachers asked fewer questions, and students talked more, asked more questions, and volunteered to speak more often. The study identifies a number of possible contextualization cues that teachers may use to signal students about what type of verbal participation structures are expected in class. When teachers do not understand the subject-matter of a lesson well, they may limit student verbal participation in an effort to avoid questions that they are unable to answer. The second year of the study (in progress) looks at discourse in a larger number of classes and a variety of class activities.

Alison Kaye is helping her biology students complete a worksheet on vertebrate taxonomy. The students are working through a dichotomous key which can be used to identify drawings of several vertebrates, including a turtle. Ms. Kaye walks around the classroom; responding to a series of student requests for help. One student, Amy, has just run through the key to find that a turtle is an amphibian. She suspects that she made a mistake:

Amy: A turtle's an amphibian, huh?

Ms. Kaye: Turtles? Let me see how you got there.

Amy: (inaudible)

Ms. Kaye: They're cold-blooded, so you go to four. Does the animal have gills? No, it doesn't. Does the animal have rough, scaly skin? Turtles?

Amy: It's not really rough.

Ms. Kaye: Yes it is. On the bottom?

Amy: Oh.

Ms. Kaye: The shell's kinda rough, right? (pauses, then turns and begins talking with the next student)

Amy: (quietly) Not really.

There is an extensive literature on teacher questioning in classrooms. Most of it comes from studies of teachers asking questions during recitations. A typical study of teacher questioning might involve having a trained observer code teacher questions as the class proceeds, or, more rarely, from a written transcript of the lesson.

A number of potentially very important issues are not addressed by this literature. Consider the brief conversation between Alison Kaye and her student,

Amy. A first pass at analyzing this discourse reveals several points that would be ignored by most studies of questioning. For example:

1. Amy began the discourse sequence with a statement phrased as a question. That was the last question she asked.

2. Every conversational turn by the teacher included a question.

3. The teacher appeared to misunderstand the commercially-prepared key, which she was using for the first time. The key asks:

   Does the animal have rough, scaly skin?

   Ms. Kaye asked Amy whether a turtle's shell is rough on the bottom. Amy did not seem to think so, but appeared reluctant to assert herself. Actually, Amy was right; a turtle's shell is not rough on the bottom. The key refers to the turtle's skin, not its shell. Ms. Kaye, who has little knowledge of vertebrate biology or taxonomy, misinterpreted the key.

My research is an interpretive study of the effects of science teacher subject-matter knowledge on classroom questioning and other forms of discourse. The study focuses on some teaching situations where the teacher knows the subject-matter very well and other situations, like the one above, where the teacher does not know the subject-matter well.

Quantitative and qualitative discourse analysis of a number of such lessons suggests that when teachers do not have a strong understanding of the topic they are teaching, they are likely to use frequent questions to control classroom conversation. When this occurs, students tend to speak for brief periods of time and withdraw from active verbal participation.

In this paper, I outline a number of ways in which a sociolinguistic approach to the study of classroom questions may help us better understand the role of teacher questions in classroom discourse. I also propose a conceptual framework

for integrating teacher subject-matter knowledge with questioning and other types of talk. The utility of the conceptual framework is explored in a study of discourse in science classrooms.

Research on Classroom Questions

To date, most research on classroom questions has focused on the effects of teacher questions on student achievement. This work, much of it originating from within the process-product paradigm (Gage, 1978; 1985), has sought to identify the types of teacher questions that are most likely to maximize student learning. A typical research question of this type might ask, "Is student achievement higher in classes with lots of high cognitive-level questions or in classes with lots of low cognitive-level questions?"

In addition to cognitive-level, research of this type has examined the effects of variations in question-asking frequency, wait time, direction of questions to specific pupils, redirection and probing, teacher reaction to pupil responses, and structuring of student responses (for reviews, see Gage & Berliner, 1984, pp. 632-647; Clark & Peterson, 1986; White & Tisher, 1986). The results of such research have been equivocal, and thus of limited utility to practitioners and teacher educators. For example, a review by Winne (1979) found that the use of high cognitive-level questions has no impact on student achievement. Redfield & Rousseau (1981), in a meta-analysis of the same literature, found a positive effect. Still others (e.g. Gall, Ward, Berliner, Cahen, Winne, Elashoff & Stanton, 1978) argue that some mixture of high and low cognitive-level questions may be optimal.

The problem with measures like cognitive-level, from the interpretive perspective, is that they often go hand-in-hand with questionable assumptions

about discourse. Process-product research on questioning, for example, pays little attention to the following issues:

- the context of questions (Who are the potential speakers and what are their interrelationships? What has occurred earlier in the conversation and in earlier conversations?)
- the content of questions (To what extent do questions focus on the salient topics of the lesson? To what extent do they identify student misconceptions? To what extent do questions force listeners to try to interpret data in the light of their misconceptions?)
- teacher thinking (How do questions vary as the knowledge of the speakers varies? How do teachers respond to different types of student talk?)
- effects of questions on classroom discourse (How do students and teachers differ in their uses of and responses to questions? What effects do teacher questions have on student verbal participation in discussions?)

Because discourse analysis is concerned with issues like these, it may be useful as a complement to process-product research, or as an alternative route to understanding the role of questions in education. A brief overview of four interpretive studies of teaching can be used to illustrate this perspective.

Hashweh (1985)

In a recent study of science lesson planning and simulated teaching and evaluation, Hashweh (1985) asked several experienced physics teachers and biology teachers to each plan several lessons on one topic in physics and one topic in biology. He found that teachers with high amounts of subject matter knowledge (e.g. experienced physics teachers preparing physics lessons) differed from less knowledgeable teachers in the way they planned to question students in evaluation. High-knowledge teachers planned to ask about material not covered in the textbook, and required students to synthesize material. Low knowledge teachers tended to use questions emphasizing recall of material found in the textbook.

Hashweh's work suggests that teacher subject-matter knowledge may affect both the types of questions teachers create and the ways questions are used to help students construct meaning.

Dobey & Schafer (1984)

Work by Dobey and Schafer (1984) suggests similar effects with elementary science teachers. Dobey and Schafer observed preservice elementary teachers leading inquiry lessons on pendulums with pairs of fifth grade students. They found that the lessons of teachers knowledgeable about pendulums were less likely to be dominated by teacher-directed activity, were more likely to pursue new or unfamiliar avenues of investigation, tended to allow more student ideas, and were more likely to stray from questions provided on a teacher's information sheet. Dobey and Schafer suggest that because knowledgeable teachers are more confident of their ability to teach an inquiry lesson, they are less likely to try to keep student activities within the scope of their subject-matter knowledge. As in Hashweh's study, Dobey and Schafer found an interaction between teacher subject-matter knowledge and teacher questioning. Their research further suggests that teacher behaviors related to subject-matter knowledge may affect the way students behave.

Dillon (1985)

Although Dillon (1985) was not concerned with teacher subject-matter knowledge, his study of teacher questions in classroom discussions suggests one way that teacher talk may influence student behavior. His analysis of discourse in five classrooms showed that teacher questions typically produced terse, factual statements by students, while non-interrogative expressions produced lengthier, more syntactically complex responses. Similar findings have been noted by others (e.g. Boggs, 1972; Edwards & Furlong, 1978).

Mishler (1975a, 1975b, 1978)

Mishler's work in elementary classrooms describes in even greater depth how questions can impact on the flow of discourse. Mishler found that students react very differently to questions from their teacher than to questions from their peers (responses to teacher questions tended to be shorter and declarative), and that students and teachers differ in the way they respond to questions in general. Teachers, for example, tend to "wrestle control" of the flow of conversation away from students who ask questions. Mishler argues that these and other characteristics of classroom discourse reflect role relationships between participants, especially along lines of authority and power.

Summary

These four studies illustrate some of the ways in which careful analysis of discourse can complement and qualify the findings of other types of research on classroom questioning. They suggest the following questions:

1. Do teachers structure classroom discourse in different ways when they understand the subject matter well, than when they do not understand the subject matter well?

2. In what ways do teacher questions serve to structure discourse? In particular, what effects do teacher questions have on student participation in science lessons?

Figure 1 shows the conceptual framework of a study I am conducting, currently in its second year, addressing these questions in the classrooms of new science teachers. The subject of this paper, and the primary focus of the study, is at the level of speech activity (units of discourse that are longer than a sentence and may consist of one discourse topic, or may consist of a set of connected topics and subtopics). This middle strand of the conceptual framework is elaborated in Figure 2. Figure 2 can be used to outline features of classroom

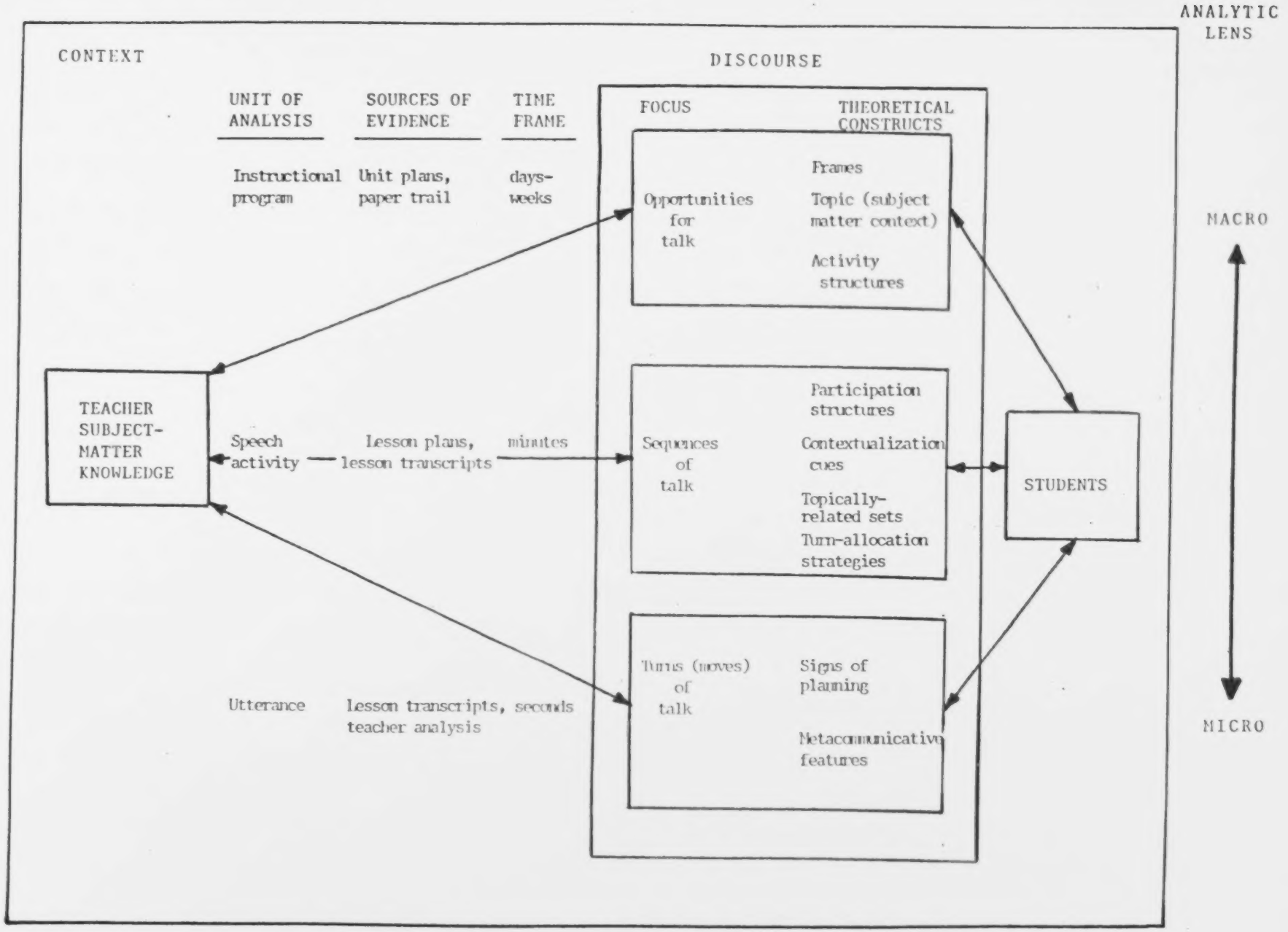

Figure 1. Conceptual framework of the study.

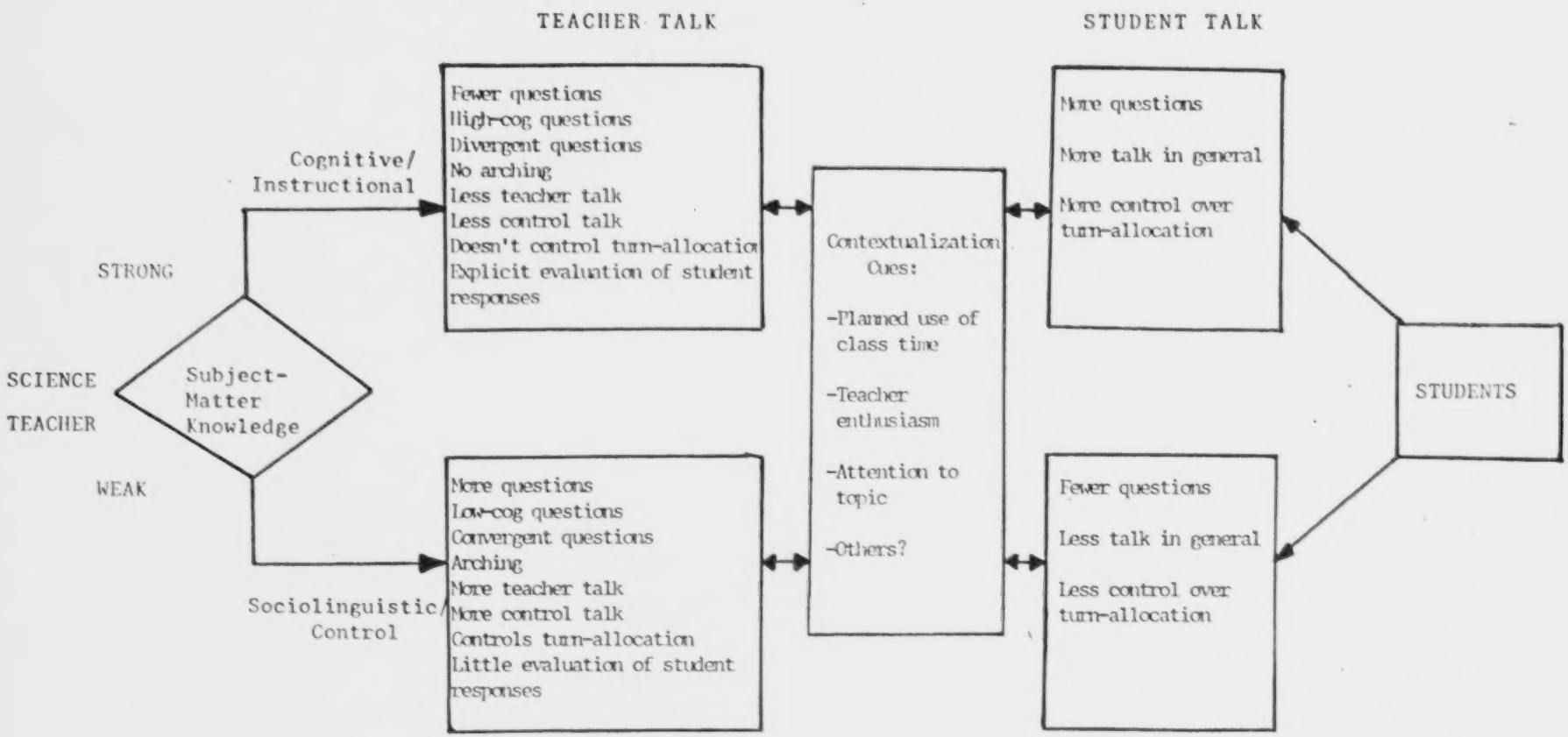

Figure 2. The middle strand of the conceptual framework: Speech Activities level.

discourse as a function of teacher subject-matter knowledge. When teachers know their subject-matter well (top branch), their talk is determined primarily by instructional concerns: how to teach the material effectively, how to motivate students, how to encourage student verbal participation in the lesson. When teachers do not know the subject-matter very well (bottom branch), their talk is determined more by issues of control: how to keep the discussion within the narrow boundaries of their knowledge, how to keep the lesson moving along, and how to minimize student disruptions.

The model in Figure 2 suggests that teacher questions in science classes will vary with levels of teacher subject-matter knowledge. For example, questions in classes for which the teacher has weak subject-matter knowledge will be used more frequently (to keep students on the defensive and thus discourage conversation from moving into areas unfamiliar to the teacher), and will less frequently be followed by teacher acknowledgement of the accuracy or inaccuracy of the student response.

Methods

Subjects

Two year-long studies of groups of new biology teachers were conducted (the second is in progress). All of the teachers in the study were interns or student-teachers in a fifth-year teacher education program; all taught for an entire year. During the first year of the study four teachers participated (1 man and 3 women), and during the second year of the study four other teachers participated (2 men and 2 women). All teachers taught biology and/or life science classes at the 9-12 grade level in public high schools in the San Francisco Bay area. The teachers were regularly visited by the author, who served the dual role of researcher and science supervisor in the subject's teacher education program.

The relative subject-matter knowledge of the teachers on fifteen biological topics was determined using a number of measures, including card sorts, transcript analysis, and end-of-study interviews.

Data Collection

For each of the teachers, classroom discourse was analyzed for a number of classes taught across a range of teacher subject-matter knowledge. In the first year of the study, pairs of lessons (one on a high teacher-knowledge topic and one on a low teacher-knowledge topic) were intensively examined by subjecting verbatim transcripts of the lessons to qualitative and quantitative discourse analysis. Anecdotal notes collected during ten other observations of the teachers and a series of interviews served as additional data sources. High-knowledge and low-knowledge classes for each teacher included the same students in the same class period, but during different units of instruction.

During the second year of the study (in progress), twelve to fifteen classes per teacher were tape-recorded and analyzed. Most of these observations were clustered over four units of instruction: two on high teacher-knowledge topics, and two on low teacher-knowledge topics. As in the first year, subjects were aware that teacher questioning and classroom discourse were being examined; they did not know that subject-matter expertise was an independent variable in the study.

For each class that was observed, data on teacher plans and interpretations of classroom events were collected during preobservation and postobservation meetings with the teacher. Observed classes were recorded with a two-track audio tape recorder and two microphones, one a wireless microphone worn by the teacher and one an omnidirectional microphone for recording student talk.

Extensive anecdotal notes on teacher and student behavior were also made during observations.

Transcription was done directly into specially-formatted computer files during several listenings of the recordings. A final listening was used to add information on the starting and ending times of teacher and student utterances. The resulting annotated transcripts were then used as input to a package of computer software which can reconstruct classroom lessons as real-time simulations. Data analysis and assessment of the validity of measures is done using this software. For example, the teachers and I use these simulations to code questions (e.g. by cognitive level), and comparisons of these codings are used as a validity check.

Because this study is concerned with theory-generating as well as theory-testing, with describing teacher and student talk within the classroom context as well as quantifying verbal behaviors, and with integrating multiple sources of evidence, the principal analytic methodology is the constant comparative method (Glaser, 1969). Constant comparison is a qualitative method which involves repeated categorization of data, ongoing formal recording of design and interpretation decisions in the form of memos and other written records, and recursive revision of theory. I have supplemented Glaser's original description of the method with computer software which facilitates the management of complex information on discourse, and permits quantitative measurement of data which would otherwise be prohibitively time consuming to analyze. Some examples of this measurement are discussed in the next section.

Results

Data from the second year of this study, which involved more extensive tape-recording than the first year of the study, are still being collected and

analyzed, so the results discussed here are primarily from the first year of the study, which was concerned primarily with discourse which occurred during teacher-led discussions and recitations. The second year of the study includes discourse from a wider range of class activities, including laboratories, seat work, and cooperative group projects.

The first year of the study was generally supportive of the conceptual framework. For example, when they were teaching topics for which they had relatively low subject-matter knowledge, teachers asked more questions, especially more low cognitive-level questions. Student talk tended to consist of brief responses to teacher questions. Conversely, in high teacher-knowledge classes, teachers asked fewer questions, and students talked a great deal more: they asked more questions, they volunteered to speak more often, and their discourse sequences were longer. Some of these findings will be discussed individually, before turning to evidence suggesting why these differences occurred.

Rate of Teacher Questioning

Figure 3 compares rates of low cognitive-level teacher questioning during discussions (as defined by the teachers) for pairs of classes, one on a high teacher-knowledge topic and one on a low teacher-knowledge topic. (Recall that during the first year of the study, tape-recording was done for only two classes per teacher. During the second year, recording was done for twelve to fifteen classes). When question cognitive level is not considered (not illustrated), teachers asked more questions in low-knowledge classes. Comparison of Figure 3 with rates of high cognitive-level questioning indicates that this increase is attributable primarily to an increase in low-level questions, not a decrease in high-level questions.

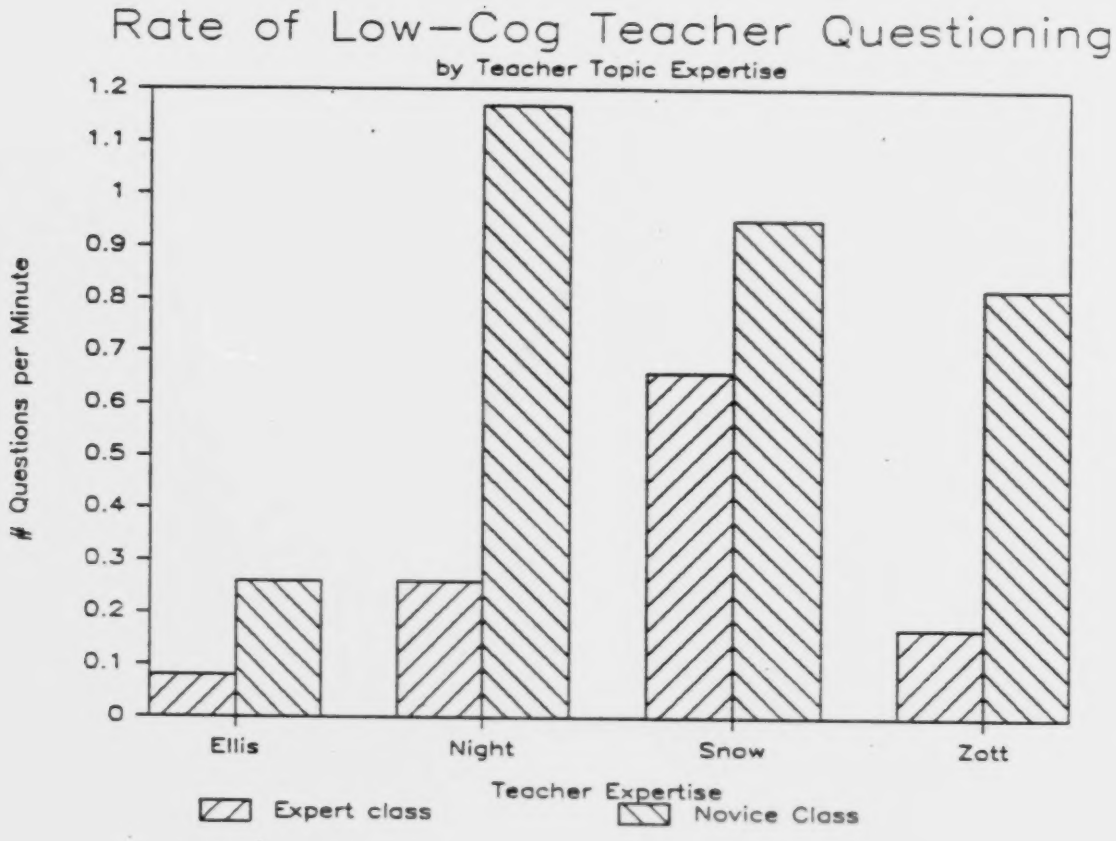

Figure 3. Rate of Low Cognitive-Level Teacher Questioning.

Coding for question cognitive-level differs in this study from most other studies of teacher questioning. Frequently, researchers code questions as low or high-level on the basis of their surface features, while the class is going on, and frequently with minimal understanding of the subject-matter of the class and the context of the lesson. Coding by cognitive-level in this study is done only after meeting with the teacher before and after the class to put the lesson in context, listening to the class several times, and carefully studying the written transcript. A paper trail of memos about coding decisions is used to document the coding process and facilitate the development of useful concepts for subsequent research.

Student Talk

In the eight classes graphed above, teachers asked questions more frequently in their low-knowledge classes. Since these teacher questions were almost invariably followed by student responses, one would not be surprised to find students talking more in low teacher-knowledge classes. This was not the case, however. A consistent (but non-significant) difference in the opposite direction was found for all four teachers: the total amount of student talk (expressed in average seconds of student talk per minute) was lower in low teacher-knowledge classes. When immediate responses to teacher questions are excluded, the difference becomes more pronounced. Figure 4 illustrates the frequency of student speech acts that occurred not in response to a teacher question. For three of the four teachers, the frequency of non-solicited student remarks was noticeably higher in high teacher-knowledge classes.

Student Question Rate

One component of this increase in student talk with higher teacher subject-matter knowledge is student-generated questions. In all classes, teacher questions were more common than student questions, but student questions occurred most

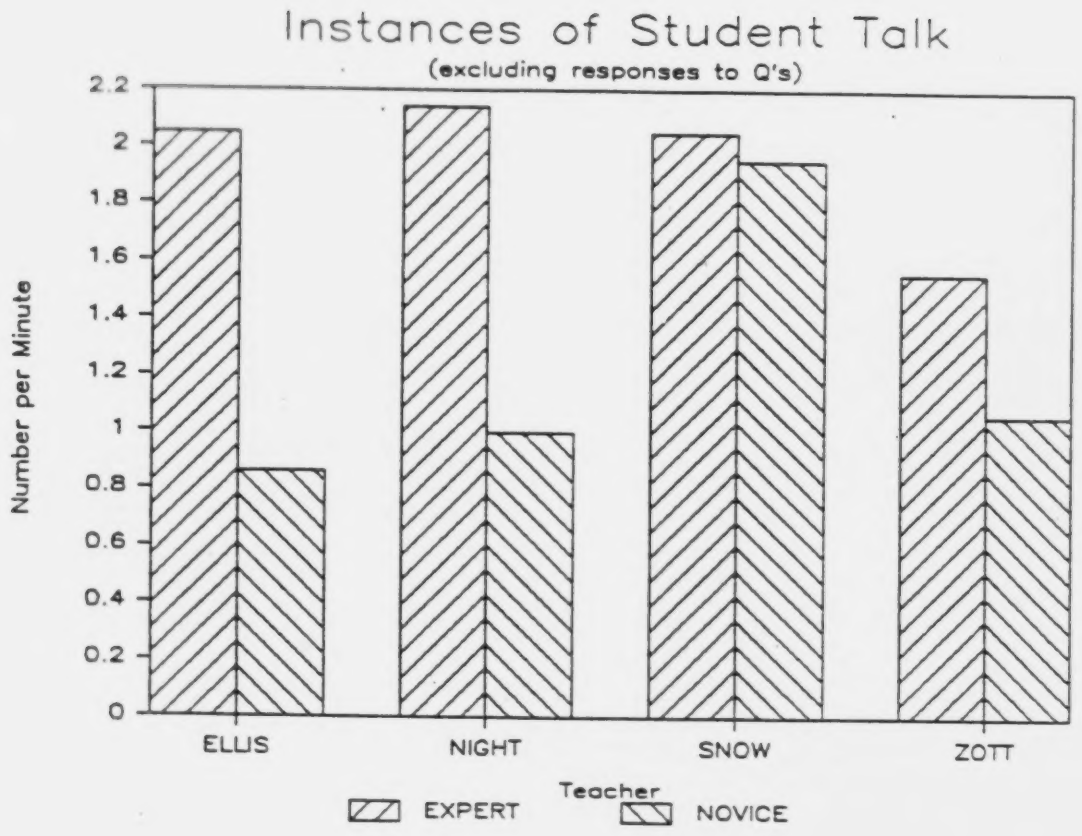

Figure 4. Frequency of Student Speech Acts (Excluding Answers to Questions)

frequently in high teacher-knowledge classes (Figure 5). When teacher and student questioning rates are compared, the effects of teacher subject-matter knowledge on the verbal fabric of the classroom can be examined. Figure 6 shows that although patterns of questioning varied by teacher (teacher Zott, for example, asked questions much more frequently than teacher Ellis), low teacher-knowledge classes were much more likely to be characterized by frequent teacher questions and infrequent student questions.

Contextualization Cues

One assumption of this study, common in sociolinguistic research but rarely made explicit in studies of classroom questioning, is the idea that classroom discourse is a joint construction between teacher and students. Through what mechanism does teacher subject-matter expertise lead to patterns of classroom discourse like increased student questioning and other verbal participation? One possible mechanism is that students monitor teacher questioning and alter their speech patterns in direct response: when teachers ask lots of questions, students talk less. This seems to be the implication of Dillon's (1985) work, discussed earlier.

A conceptually richer explanation for changes in classroom discourse as a function of teacher knowledge can be grounded in the sociolinguistic notion of a participation structure (Philips, 1972). Participation structures are communicative networks linking typical arrangements of speakers and listeners. Participation structures have associated with them rules for participation which are generally understood by speakers and listeners. So, for example, rules governing students' talk are different within the participation structure of a "test" than within the participation structure of a "discussion." If a teacher were trying to limit student questions, because of self-perceived teacher inexpertise with the topic, he or she

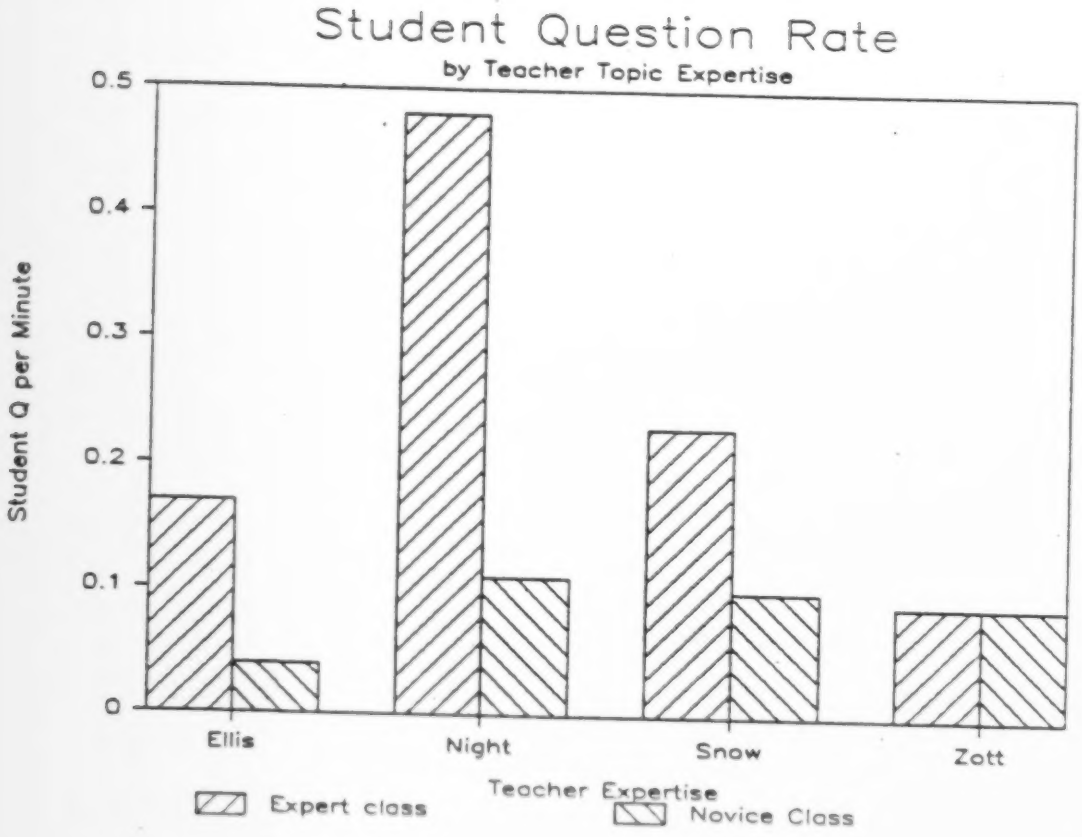

Figure 5. Student Questioning Rate (that is, the rate students ask questions).

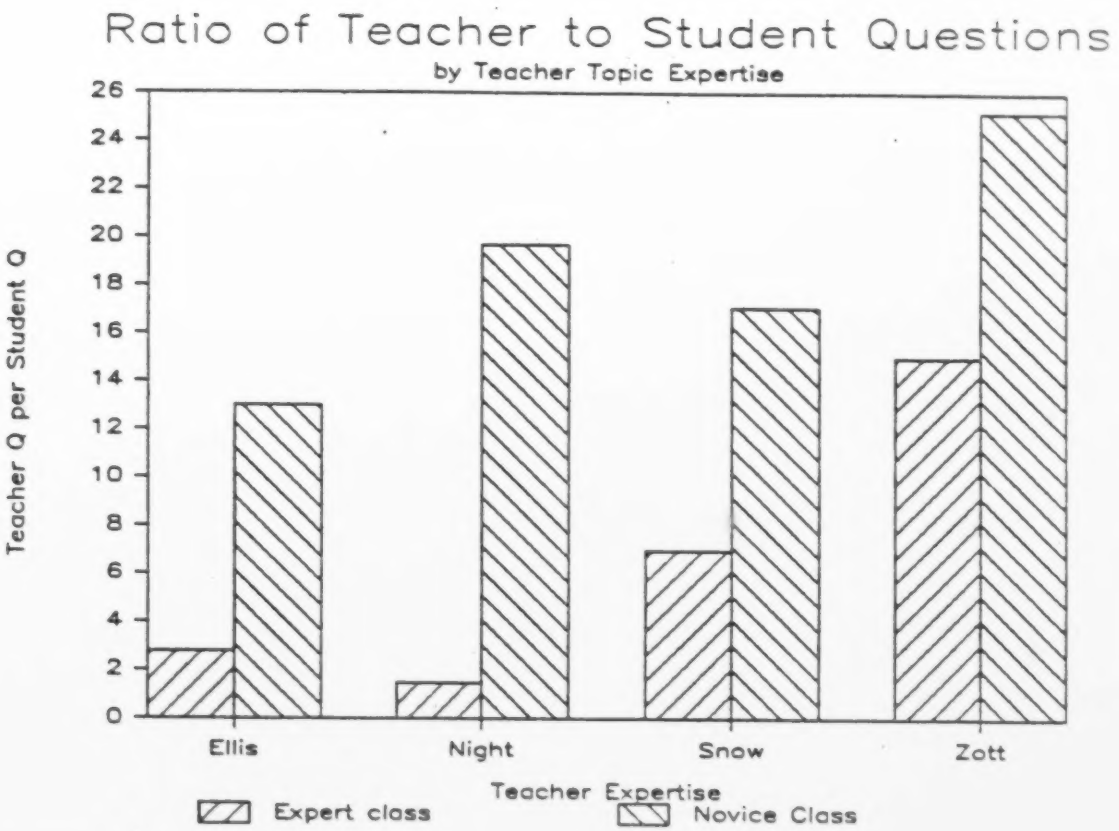

Figure 6. Ratio of Teacher to Student Questions.

might (inadvertently, perhaps) signal students that a participation structure calling for limited student questions was in effect.

The conceptual framework of the speech activities level of this study (Figure 2) lists some possible "contextualization cues" (Gumperz, 1982) that teachers may use to signal students that particular participation structures are desired by the teacher. Although a thorough description of the use of contextualization cues awaits further analysis of this year's data, examples of a couple of possible cues may illustrate their use.

Teacher Enthusiasm

Data from the first year of the research were studied in several ways to determine whether teachers somehow communicated their own enthusiasm with topics they understood well, and lack of enthusiasm with topics they did not understand well. Obvious teacher enthusiasm might serve as a contextualization cue prompting greater student participation.

Differences in teacher enthusiasm across topic-expertise appeared in the first year's data, but are difficult to summarize without lengthy descriptions of teacher and student talk. Furthermore, given that the researcher knew a priori which classes were high-knowledge and which classes were low-knowledge, it is impossible to be sure whether perceived anecdotal differences in teacher enthusiasm are real or observer effects. Analysis of data from the second year of the study, which are more extensive, may uncover ways of objectively and succinctly describing overt teacher enthusiasm.

Indirect measures of teacher enthusiasm are easier to document. One such measure is the teacher's use of class time.

Use of Class Time

While the teachers in the first year of the study knew that I wanted to observe a class discussion, and on tape-recorded days, their lesson plans were devoted mostly to a discussion, lots of other activities typically occurred. Reading the bulletin, school administrative business, passing out papers, talking about tests, and setting up labs took at least some of the time in each class.

Three of the four teachers spent considerably more time on class discussions on high-knowledge days than on low-knowledge days. Overall use of class time, however, is not itself always going to be useful as a contextualization cue. To serve as a cue, a signal from the teacher must occur early in the class, certainly before or during the discussion of interest. With this in mind, time allocation before class discussions was graphed (Figure 7). Here a topic-expertise effect is also seen. Teachers appear to "put off" class discussions in low knowledge classes longer. In effect, the discussion takes second priority to the other activities to be done that day (in the cases of Ellis, Night, and Snow, low-knowledge classes were delayed by a lab setup, some student group work, and filling out student paperwork for an upcoming Career Day). Furthermore, in these three cases, these non-discussion activities ended up taking about twice as much time as the teacher had planned.

In high-knowledge classes, non-discussion activities occurred (including a lab setup, a film, passing back papers, and going over a test), but were delayed until after the class discussion, thereby ensuring that enough time would be available for the discussion.

Second Year of the Study

Data for the second year of the study are still being collected and analyzed, and it is too early to assess how well the findings summarized above describe the

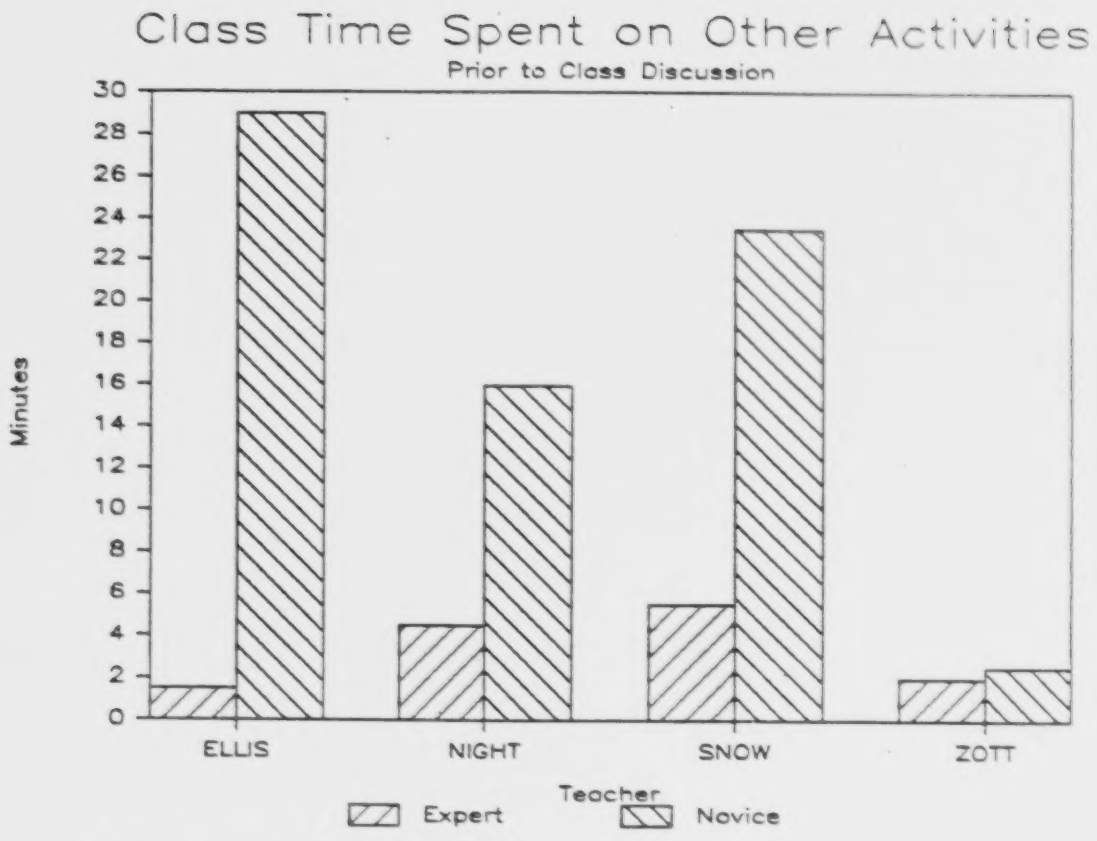

Figure 7. Class Time Spent on Other Activities Before Class Discussion.

classes of four new teachers. As of early March, 35 classes had been recorded, of which 24 were on low or high teacher-knowledge topics (the rest were intermediate or unclassified). Because the study has been broadened to include classroom discourse in a variety of settings (not just discussions and recitations), the task of comparing discourse patterns in high and low knowledge settings must be preceded by the development of a careful description of the types of activities observed. This description is a first step in analyzing participation structures in science classrooms.

One function of broadening the scope of the study is to provide a way of triangulating findings like those described earlier. For example, if teachers do try to avoid difficult student questions when they do not understand the subject well, we might expect to find activities which minimize student questions in a public forum more common in low-knowledge classes. There is some evidence of this in the 24 classes recorded so far during the second year. For example, students were assigned seatwork (typically some type of worksheet) in 46% of the low-knowledge classes observed (6 out of 13 low-knowledge classes) but only 18% of high-knowledge classes (2 out of 11 high-knowledge classes). As we saw in the transcript fragment of Ms. Kaye's class, during student seatwork, teachers may be asked questions they cannot correctly answer, but their incomplete knowledge is not likely to be displayed to the entire class.

Implications and Cautions

Little research has been done on the effects of teacher subject-matter knowledge on classroom discourse, so much of the theory and analysis in this study has been developed in a heuristic fashion. While the qualitative method of constant comparative analysis is well suited for research like this, there are

numerous theoretical pitfalls which require constant attention. For example, most of the results described here are based on very few classes observed for a small sample of science teachers just beginning their careers. With two or three years of teaching experience, these people may routinize their behaviors to the extent that differences in questioning behavior based on subject-matter knowledge disappear. Furthermore, new teachers often report that they don't really understand a topic until they've taught it a few times. It is important to keep in mind that subject-matter knowledge continues to change after teacher education and the formal study of science in college end.

At this point, many of the results presented here might be explained in terms of plausible rival hypotheses. It is possible, for example, that in the first year of the study, the topics teachers were most knowledgeable about just happened to be the topics their students inherently found most interesting. To address this possibility, topics in the second year of the study were chosen to test this alternative hypothesis (by observing topics which are high-knowledge for some teachers and low-knowledge for others).

Although many questions related to this research are not yet answered, several points seem clear. First, research on questioning in classrooms needs to pay greater attention to issues of context, content, and teacher thinking. A question which appears at first glance to be a cognitively-demanding question may in fact be a simple memory-recall question, if the teacher asked and answered the question earlier during the period, or on the preceding day.

Second, it is clear that a unidirectional cause and effect relationship between teacher questions and student achievement is much too simplistic. Yet that model describes many extant studies of classroom questioning, which may, for example, attempt to relate teacher questions read in a lesson script with student

scores on an achievement test. Discourse in a classroom is a joint production of numerous people. What starts out as a question of one type may turn into something quite different over the course of a set of teacher and student utterances. While there is merit in trying to relate teacher behaviors with student achievement, such research needs to be grounded in a realistic understanding of how discourse is produced.

Third, the types of activities teachers and students engage in have repercussions for the types of verbal interactions they have. While recitations and discussions are common instructional strategies in science classrooms, they are not the only strategies. The meanings that students and teachers ascribe to each others' questions need to be sought across a variety of types of instruction.

Fourth, we must keep in mind that high subject-matter knowledge does not necessarily lead to better teaching. The goals of the teacher and the instructional program may actually be circumvented by too much teacher subject-matter knowledge. For example, in the first year of the study, there was some indication that student questions on high-knowledge topics often meant that the topic of discourse wandered far from the teacher's lesson plan. Depending on the needs of the class and the available time, such wandering may be beneficial, but it is easy to think of situations in which wandering from the topic may leave students confused about the meaning of the instruction.

Finally, it appears that there are differences in classroom discourse which are related to the subject-matter knowledge of the teacher, and that at least some of these differences involve changes in the form and frequency of teacher questions. This finding has implications for teaching practice and for interpreting research on teaching. For example, research which shows a link between teacher questions and student achievement needs to consider the possibility that subject-

matter knowledge is a mediating variable. Do teachers who know their subject well feel more comfortable waiting several seconds for a student response? Do they consistently ask better questions? If so, improvements in science teaching might be predicated not on teaching science teachers how to ask questions better, but on improving their subject-matter knowledge in areas they are weak.

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